Middle East Journal of Applied Science & Technology (MEJAST)
Volume 7, Issue 1, Pages 135-145, January-March 2024

Development of Animal Feed Pellet Making Machine

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DOI: https://doi.org/10.46431/MEJAST.2024.7107

Article Received: 26 November 2023 *Article Accepted: 29 January 2024* *Article Published: 30 January 2024*

ABSTRACT

The purpose of this study was to develop and conduct tests on a power-driven animal feed pellet manufacturing prototype for the production of animal feed. The pellet feed manufacturing machine included a hopper, a pelleting chamber, a pellet roll, a die plate, an exit, and a frame. It was propelled by a 3-hp electric motor. The machine's overall dimensions were 800mm*1170mm*560mm. It can make animal feed pellets with an average diameter of 10 mm, a length of 5-7 cm, and a weight of 1.78 g. On wheat-based feed components, the machine's actual pelleting capacity, throughput capacity, and pelleting efficiency improve from 60.2 to 64.6 kg/hr, 71.1 to 74.1kg/hr, and 84.67 to 87.18 of 57% as moisture content increases from 15 to 25%. As moisture content increases from 15 to 25%, un-pelleted feed ingredients reduce from 15.33 to 12.82% and 10 to 7% on wheat and maize-based feed ingredients, respectively.

Keywords: Pellet; Actual Capacity; Throughput Capacity; Pelleting Efficiency; Cost Analysis; Break-even Point; Pelleting Die and Roll.

1. Introduction

Pellets are characterized by the following description: "feeds formed by extruding ingredients or mixtures by compacting and forcing through die openings by any mechanical process." Pelletizing is the process of molding finely divided, sometimes dusty, unpleasant, and difficult-to-handle feed material into larger particles by the use of heat, moisture, and pressure [1], [2], [14]. When compared to un-pelletized feed, these larger particles are easier to handle, more portable, and usually result in better feeding results. Feed is the most costly component of animal production.

As a result, the efficacy of its execution, or control over quality, can have a significant impact on an enterprise's performance. A feed's value is determined by the amount of a given component in the feed that the animal can use to meet the needs of different body processes. The goal of cattle feed preparation is to increase the efficiency with which nutrients are utilized [3], [15].

According to the study, feeding pellets to specific cattle has numerous advantages. According to [4], and [16], highly compressed pellets make storage and transportation easier by conserving space, extending storage life, and allowing large volumes to be handled affordably. As stated by [5]' pelleted feeds have several advantages for livestock producers, including reduced feed waste, less selective feeding, higher feed efficiency, better handling qualities, eradication of unwanted microbial organisms, and improved bulk density. Pelleting increased nutritional value and improved chick growth, according to Scholar [6], [18].

However, most small and medium-sized livestock farmers cannot afford feed pellet production machinery, resulting in poorer productivity. In other words, generating feed pellets has traditionally been a difficult operation unless a basic cost-effective pelleting machine is available, and formerly commercially available feed pellet manufacturing machines were expensive and out of reach for small farms. As a result of the facts and benefits stated above, a portable pellet feed-making prototype was created and assessed.

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2. Materials and Methods

2.1. Materials

Various components would be selected for different portions based on their toughness, accessibility, and affordability.

Table 1. The List of main parts and Material made from:

No	Component	Made from
1	Roller	Mild steel
2	Die	12 mm sheet metal
3	Shaft	Steel bar
4	Hopper	Sheet metal 1.5 mm
5	Frame	Square pipe
6	Motor	Electric 3hp
7	Knife	Stainless steel

2.2. Site description

The effectiveness of the feed pellet-generating equipment has been evaluated and manufactured at the Asella Agricultural Engineering Research Center in Asella City.

2.3. Machine description

The feed pellet-producing machine, as illustrated schematically in Figure 1, was made up of the following components: a hopper, a pelleting chamber, a frame, an electric motor, a die plate, a roller plate, and an output. The machine's overall length, height, and width were 800mm*1170*560mm.

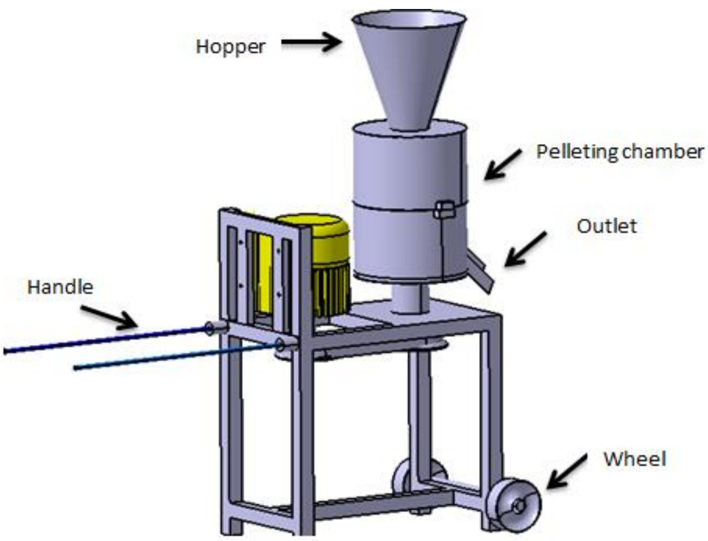

Figure 1. Pellet feed-making machine and its parts

The hopper: It was where the formulated feeds were delivered and transported as pellets to the die plate via the two pellet wheels. It is built in the shape of a cone. The hopper's bottom and top diameters are 11 cm and 30 cm, respectively, with a height of 23 cm.

Pelleting chamber: The interior of the pellet production machine, which includes rotating moveable pellet rolls and pellet dies covered with 2mm sheet metal and attached to the frame Using a steel bar to endure the tremendous force exerted by the whirling die plate and pellet rolls. It is where feeds are extruded before being driven via the pellet rolls' apertures in the die plate.

The pellet roll: It was pressing the feed ingredients before them being discharged into the hollow die plate. The two sets of fluted pellet rollers received a pair of bearings each and were installed on a 30mm diameter shaft, allowing them to freely circle as the die plate revolved. To decrease slippage during operation, the pellet rolls were also outfitted with P-block 206 bearings on both sides.

Plate die: The component that turns prepared feeds into cylindrical-shaped solid components, or pellets. The die plate was attached with shafting of 30mm diameter to allow it to revolve when the electric motor was switched on. It was made of a metal plate 30 cm in diameter and 12mm thick to handle the weight and pressure caused by the rotating pellet rollers. It has 546 holes, each of which is 10 mm in diameter.

Outlet: The pelletized feeds were dumped here for collecting.

Frame: The frame supported the other components. It was a stiff construction built to withstand dynamic forces. The frame was built with a 4mm*40mm square bar to ensure that the entire body of the feed pellet-producing machine was supported by the frame.

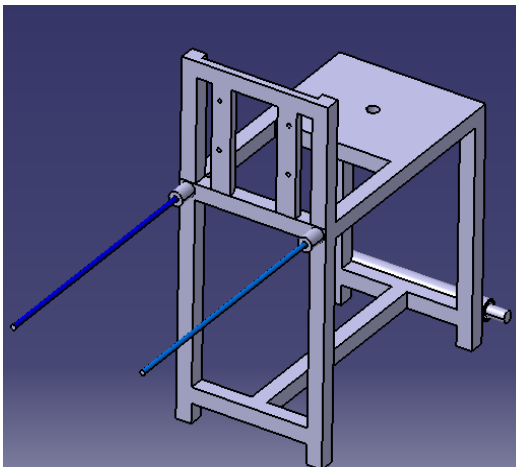

Figure 2. Frame structure (Cad Model)

2.4. Working principles

The machine ran on roll-type extrusion force. The formulated feed that must be turned into pellets is fed via the hopper and then towards the pelleting chamber. The pulley of the die pellet shaft was attached to the pulley of the electric motor, allowing the power source to rotate the die pellet shaft. The spinning of the die drives the rollers to squeeze and compress feed material into the die holes, resulting in feed pellets. A blade sliced the created feed pellets and discharged them through the outlet.

2.5. Selection of pellet die hole diameter

According to [7] Table 2 was the ideal pellet die diameter for various animals.

Table 2. The sizes of pellet die holes for various animals.

Animal	Pellet size Dia (CM)
Fishes	0.15 - 0.2
Chickens	0.3 – 0.4
Goat	0.8 - 1
livestock	1.2 – 1.3

So, 10 mm in diameter was selected for goats and sheep accordingly.

2.6. Determination of shaft Diameter

The feed pellet making has one main shaft for the die pellet and its diameter determined using maximum shear stress theory

$$d^3 = \frac{16}{\pi\tau_{\max}}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (1)$$

Following further computations, a shaft with a diameter of 25 mm was chosen.

2.7. Horsepower calculation

The horsepower necessary to run the equipment was determined as a combination of the powers needed for powering the pellet roll assembly, the die plate assemblage, and the weights on them, as well as the force needed to conquer friction resistance. The total amount of horsepower (Pt) required for the pelleting processes was determined using Equation (2) [8].

$$Pt = P + 10\%\, P \qquad (2)$$

Pt = total power of the machine, P = power for die plate rotation

Following further computations, a 3 HP motor was chosen to fit the purpose.

2.8. Determination of Pulley Diameter

Pulleys and belts preference: the equipment needed a pair of pulleys, one on the die shaft and one on the electric motor, as the main drive. Power was delivered from an electric motor to the die shaft via a single belt. Aluminum pulleys were chosen because of their widespread availability and affordable cost. The pulley on the electric motor shaft had a diameter of 90 mm and a speed of 1400 rpm at first. The dimensions of the pulleys on the die's drive shaft, the center distance between the pulleys, the belt length, and the belt speeds on the opposite shaft were determined according to [9],[13] as follows;

$$D_1 N_1 = D_2 N_2 \qquad (3)$$

$$C = \frac{D_1 + D_2}{2} + D_1 \quad (4)$$

$$V = \frac{N2\pi D2}{60000} \quad (5)$$

$$L = 2C + 1.57(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4C} \quad (6)$$

Where D1 and D2 are the sizes of the operating and operated pulleys (mm), N1 and N2 are the rpm of the operating and operated pulleys, C is the central spacing between the two subsequent pulleys (mm), L is the length of the belt (mm), and V is the belt speed (m/s). So calculations yielded a 250-mm pulley diameter on the die shaft, 260-mm central spacing between two pulleys, and a 1078-mm belt length.

2.9. Performance evaluation procedure

During each test run, the materials fed into the hopper and exiting the outlet (mass of input feed and mass of pellet retrieved) were weighted with a digital balance. The machine efficiency and capacity were assessed with Eqs. (7 and 8) by [10-12] scholars as follows:

$$TC = \frac{W_i}{T} \quad (7)$$

$$AC = \frac{W_P}{T} \quad (8)$$

Where TC stands for throughput capacity in kilograms per hour, Wi stands for the mass of the initial supplies in kilograms, and T stands for the period spent in hours. AC stands for actual capacity in kilos per hour. Wp denotes the weight of pellets collected in kilograms.

Pelleting efficiency is defined as the ratio of genuine feed pellets that are collected at the primary pellet exit to the total feed consumed during a specified period. At the end of each session, the feed mixture retained in the pelleting chamber was manually removed and weighed. The pelleting effectiveness of the pelletizer was determined by comparing the amount of feed pelleted and retained to the entire amount of feed ingredient provided to the pelletizing machine. The pelleting machine's effectiveness was determined using the following equation.

$$P_E = \frac{W_P}{W_i} x100\% \quad (9)$$

Where P_E denotes pelleting efficiency in percentage, Wp is the amount of real feed pelleted in kilograms, and Wi denotes total feed mass input in kilograms.

2.10. Experimental Design and Treatment

To assess the prototype's performance, two levels of designed feed mixture (wheat and maize-based) and three degrees of moisture content were used. The experimental design was factorial, with 18 experimental units measuring 2 x 3 x 3.

3. Results and Discussions

A feed pellet production machine's performance was investigated to determine its pelleting capacity and pelleting efficiency at three distinct levels of moisture in the designed feed ingredients. Before the start of the genuine trials, the prepared feed combination was made and moistened to a set level before being stored for a specified number of times before being put into the pelleting machine to ensure practically consistent moisture content within the ingredients. The research was conducted at the Asella Agricultural Engineering Research Center.

Figure 3. A pictorial view of the machine and its output

Table 3. Capacity and pelleting efficiency of machine at various moisture content and ingredient levels

Ingredient	MC (%)	Performance parameter			
		Actual capacity	Throughput capacity	Pelleting efficiency (%)	Unpelleted (%)
Wheat-based	15	60.2a	71.1a	84.67a	15.33
	20	63.4b	73.7a	86b	14
	25	64.6b	74.1a	87.18b	12.82
Maize-based	15	64.8a	72a	90a	10
	20	68.25b	75a	91b	9
	25	74.4b	80a	93b	7

The same letter in the column has no significant difference at 5%, MC-moisture content.

3.1. Throughput and Actual Capacity

The pelleting machine generated an actual capacity of 74.4 kg/h at 25% moisture content and a throughput capacity of 80 kg/h, as indicated in Table 3. The variance in throughput and actual ability for different moisture contents of the two combinations was significantly different at the level of 5%, with maize-based feed components achieving the highest performance and actual pelleting ability at a moisture content of 25%. The feed mixture with the lowest moisture content had the lowest throughput and actual capacity, which deviated notably from a moisture percentage of 25% at the 5% level. A moisture level of 25% in the feed ingredient resulted in the best combination of throughput capacity of 80 and 74.1 kg/hr for maize and wheat-based ingredients, respectively. Whereas the

maximum actual pelleting capacity of 64.6 and 74.4 kg/hr was recorded at 25% moisture content on wheat and maize-based ingredients, respectively.

3.2. Pelleting efficiency

The pelleting machine exhibited a maximum efficiency of 93% on maize-based feed mixtures with 25% moisture content and a minimum pelleting efficiency of 84.67% on wheat-based feed mixtures with 15% moisture content. Differences in pelleting efficiency between two feed ingredients, on the other hand, were not statistically significant at the 5% level. The greatest efficiency at 25% percent moisture was possibly owing to a smaller quantity of substance remaining in the pelleting compartment unless pelleted, but it was additionally due to the mix of feed ingredients being sufficiently wet to hold the fragments together and prevent them from separating post pelleting. The finding obtained was supported by [10], [17]. The percentage of unpelleted feed ingredients decreased from 15.33 to 12.82% and 10 to 7% as moisture content increased from 15 to 25% on wheat and maize-based ingredients, respectively.

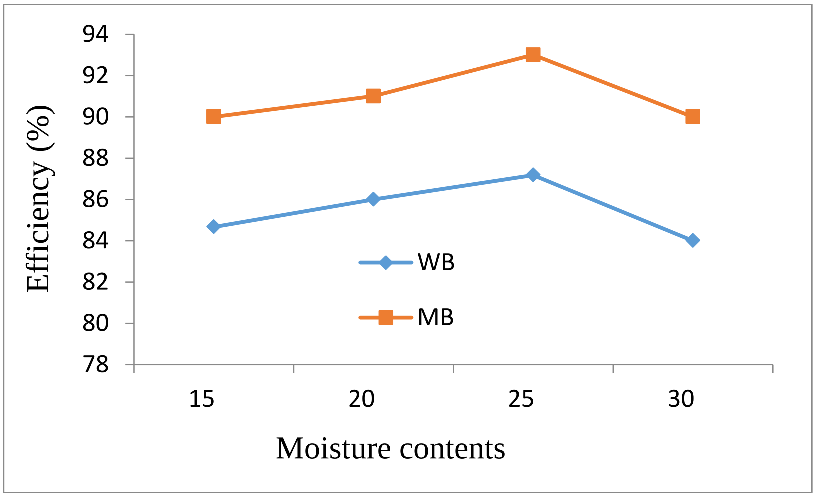

Figure 4. The relation of moisture content with pelleting efficiency

3.3. Cost analysis of a feed pellet-making machine

Table 4 illustrates the cost factors and items of the feed pellet-producing machine. The machine costs roughly 9119.07 birr without an electric motor and 20119.07 birr with a 3-hp electric motor. The fixed cost comprises three cost items: depreciation, interest, and shelter, whereas the variable cost consists of electric costs, labor costs, repair costs, and maintenance costs. Table 4 shows that the feed pellet-producing machine costs only 0.56 birr per kilogram.

Table 4. The cost factors and items of the feed pellet making machine

	Cost items/factors	ETB
1	Cost of feed pellet-making machine	
A	Raw Material cost	6901.84
B	Materials wastage = 2.5 % of a	172.55

C	Production cost (machine + labor)	1157.78
D	Overhead cost = 5% of c	57.89
E	Profit = 10 % of (a + b + c + d)	829.01
F	Sell tax =15% of (a + b + c + d + e)	2456.79
G	Selling price = (a + b + c + d + e + f)	9119.07
H	Electric motor 3HP (Assume)	11,000
	Total cost	**20119.07**
2	Life of the pellet-making machine	8 yrs
3	Annual use	1440 hr
4	Annual fixed cost	
	a. Depreciation	2263.4
	b. Interest (12 %)	1463.66
	c. Shelter (0.01 % of P)	2.01
	Total	3729.07 birr/yr
	Total	**2.59 birr/hr**
5	Variable cost	
	a. Repair and maintenance (0.01 % P)	2.01 birr/hr
	b. Labor (two labors, 150/day)	37.5 birr/hr
	c. Electric (25 kw /quint = 6.83 birr/quintal)	5.46 birr/hr
	Total	44.97 birr/hr
6	**Total cost**	**47.56 birr/hr**
7	Cost of Pelleting (80 kg/hr)	0.56 birr/kg

ETB = Ethiopian birr

3.4. Break-even point

Table 4 shows that the equipment has an initial cost of 20119.07 Birr and anticipated life duration of 8 years. Based on fundamental assumptions and existing market practice, the annual fixed cost of operating the gadget is 3729.07 Birr. Interest is assumed to be 12%, shelter is assumed to be 0.01% per year, repair and maintenance is assumed to be 0.01% per hour, operation per day is 8 hours, annual use is 1440 hours, and the custom rate is 1.06 birr/kg.

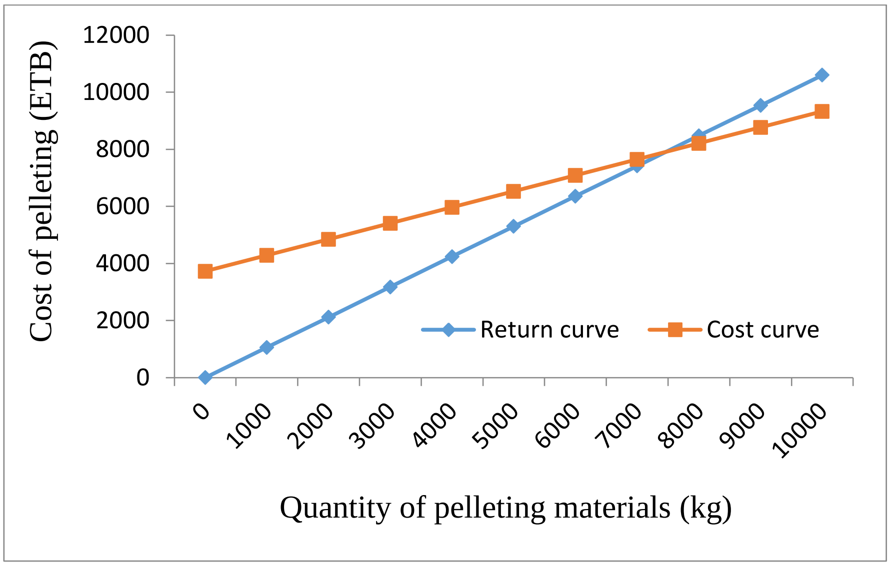

Figure 5. Relationship between the cost of operation of the feed pellet-making machine and the quantity of pelleting materials

To break-even on the cost of fabrication, the pellet-producing machine must pellet more than 7.5 tons of ingredients in a year. Figure 5 depicts the cost curve, with the break-even quantity highlighted. If the available number of materials is larger than the break-even quantity, the utilization of the pellet-making will result in profit. Otherwise, the machine is costly to operate when the available quantity is less than the break-even quantity.

4. Conclusion

The following conclusions were obtained based on the findings:

✓The pelleting machine's development and evaluation provided pelleting efficiencies of 87.18% and 93% on wheat and maize-based feed components, respectively.

✓The feed pellet machine has an actual pelleting capacity of 74.4 kg/h and can handle a maximum of 80 kg/h.

✓Overall, this study found that manufactured feed pellets are less expensive and have superior nutritional quality than commercially available feed pellets, allowing for a significant reduction in reliance on commercially available high-cost feed pellets.

5. Recommendation

According to the findings, the pellet feed-making machine may turn dusty mixed ingredients into pellets and create a substantial volume of pellets. Because of its high performance, it was recommended that this pellet feed production equipment be copied and given to farmers or users. Further development of the power unit and drive system to offer a diesel engine rather than an electrical one is required to improve its usability in remote areas, particularly in isolated areas in which electrical continuity is a concern.

Declarations

Source of Funding

This study has not received any funds from any organization.

Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

Both authors took part in data collection, literature review, analysis, and manuscript writing.

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